

"Note on the Formation of Solids at Low Temperatures, particularly with Regard to Solid Hydrogen." By MORRIS W. TRAVERS, D.Sc., Professor of Chemistry at University College, Bristol. Communicated by Sir W. RAMSAY, K.C.B., F.R.S. Received February 4,—Read February 18th, 1904.

In the year 1902 Dr. Jaqueroz and I carried out some experiments on liquid and solid hydrogen with a view to determining its vapour pressure on the scales of the constant-volume helium and hydrogen thermometers. We found that hydrogen remained liquid down to $14^{\circ} \cdot 2$ (He scale), the lowest temperature to which we could reduce a large mass of the liquid by means of the pump at our disposal. When, however, a small quantity of liquid hydrogen, cooled to $14^{\circ} \cdot 2$ in a glass tube immersed in the liquid contained in the large vacuum vessel, was allowed to evaporate under reduced pressure, it solidified when the pressure fell to 49 or 50 mm. of mercury. This pressure corresponds to a temperature of $14^{\circ} \cdot 1$ on the helium scale. The presence of the solid was determined by mechanical means, and it was not possible to observe its appearance.*

Dewar gives the melting point of hydrogen at about 15° absolute, and the melting pressure at 55 mm. of mercury. He describes its appearance as that of "frozen foam," or as "clear transparent ice."†

It appeared to me worth while to carry out a few experiments to try to determine whether solid hydrogen formed definite crystal, or indeed whether the glassy substance was a true solid or merely a highly viscous fluid. My meaning will become clearer if I give an instance in which both such changes occur.

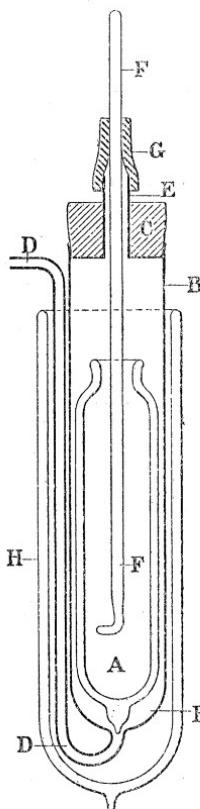
If an organic liquid, such as ethyl aceto-acetate, is cooled slowly to the temperature of liquid air, it is converted into crystalline solid, the formation of the crystals commencing when the liquid is cooled to about -150° C., usually at several points on the side of the vessel, and spreading rapidly throughout the mass. If, on the other hand, the liquid is cooled very rapidly, a hard glassy substance is formed, and though crystals may begin to appear, they will only do so locally, as the velocity of crystallisation decreases rapidly as the viscosity of the liquid increases. The glassy substance is really a liquid of high viscosity; it is formed with perfect continuity from the normal liquid state, and should differ from the solid (crystalline) form in its physical properties. Such a substance might, for convenience, be called a pseudo-solid.

* 'Phil. Trans.', A, vol. 200, p. 170.

† British Association, Presidential Address, 1902. See also paper on "Solid Hydrogen," 'Brit. Assoc. Report,' 1899, reprinted in 'Nature'; also 'Roy. Inst. Proc.', 1900.



In investigating solid hydrogen the apparatus shown in the accompanying figure was employed. The liquid hydrogen was introduced into a small clear-glass vacuum-vessel 15 cm. long and 4 cm. in internal diameter.



This vessel was placed inside a glass tube BB, which communicated with an exhaust pump through a tube DD sealed to it, and was closed by a rubber stopper C. A short glass tube E, 6 mm. in diameter, passed through the stopper, and through it passed the stirring rod FF. To allow of free rotating motion to the stirrer, and to make the apparatus gas-tight, a short piece of rubber tube G, was passed over the end of the tube E and was wired to F. The lower part of the apparatus was contained within the vacuum vessel H, which contained a small quantity of liquid air.

When the liquid hydrogen was made to boil *in vacuo*, its temperature fell, but the liquid did not appear to become more viscous. At length films of a colourless glassy substance formed at the surface, and broke away as the bubbles rose. After a short time the vessel became filled with these flakes, and while in this condition stirring, by giving the top of the rod F a rotatory motion, did not appear to indicate that the portion which remained liquid had undergone any considerable increase in viscosity. After a time the mass contained so much solid that it became pasty, and finally the whole of it appeared fairly homogeneous.

The solid evaporated fairly rapidly, so that after about 10 minutes only a hollow cylinder of it, about 3 cm. long and 2.5 cm. in diameter, remained. This had the appearance of a film of ice which had partly thawed, consisting of clear granules connected by thinner and less transparent portions of solid. No crystals were observed on either of the three occasions on which the experiments was carried out. An attempt was made to examine the solid in the field of a polariscope, but it was unsuccessful.

Though there is no direct evidence of the formation of crystalline hydrogen, my experiments lead me to the belief that solid hydrogen is a crystalline substance and not a pseudo-solid. The sharpness with which the solid hydrogen is formed, and the constancy of the apparent melting pressure, are distinct evidence in favour of this conclusion, though it must be allowed that the rate of change in viscosity, when the temperatures are measured on the Centigrade scale, will probably

appear to be more rapid at low temperatures than at high temperatures.

The whole question of the formation of solids at very low temperatures is of great interest both from a physical and from a biological standpoint. It is quite possible that if living organisms were cooled only to temperatures at which physical changes such as crystallisation take place with measurable velocity, the process would be fatal, whereas if they once were cooled to the temperature of liquid air, no such change could take place within finite time, and the organism would survive.*

These experiments were made in connection with some investigations which were being carried out at University College, London, with the assistance of a grant from the Royal Society. As I am at the moment unable to continue the work, I have decided to publish this note.

“A Contribution to the Study of the Action of Indian Cobra Poison.”†

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On special duty for Snake Venom Research under the orders of the Secretary of State for India. Communicated by Professor Sir THOMAS R. FRASER, F.R.S. Received January 18,
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(Abstract.)

Previous Work on the Subject.

Brunton and Fayrer‡ discussed the pharmacology of Cobra venom at some length; they attributed the effects of the poison to its action on the cerebro-spinal nerve-centres, especially on the respiratory centre. They observed that Cobra venom had a direct action on cardiac muscle, and that it also affected the heart through the vagal system, but they did not lay much stress on circulatory failure. They surmised that the high and maintained blood pressure of a cobraised animal was due to arteriolar constriction, but did not attempt to explain how this was brought about. Amongst the many other points of interest they took up, was the influence of artificial respiration in cobraism.

* Experimental results are given by Macfadyen, ‘Roy. Soc. Proc.’ vol. 66, 1900, pp. 180, 339, 488; Swithinbank, ‘Roy. Soc. Proc.’ vol. 68, 1901, p. 502.

† Owing to the kindness of Professor Sir Thomas Fraser and of Professor E. A. Schäfer, the writer was enabled to carry out this research in the Pharmacological and Physiological Laboratories of the University of Edinburgh. Towards the expense of this research, grants were received from the British Medical Association and from the Moray Fund for the Endowment of Research (Edinburgh).

‡ ‘Roy. Soc. Proc.’ vols. 21, 22, and 23.